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RADIOGRAPHIC STUDY OF THE BURNING PROPELLANT GRAIN IN THE SUBROC GAS GENERATOR PACKAGE WOX-5A (U)

1 NOVEMBER 1962

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 62-194

RADIOGRAPHIC STUDY OF THE BURNING PROPELLANT GRAIN IN THE SUBROC GAS GENERATOR PACKAGE WOX-5A (U)

Prepared by:

R. H. Stange

ABSTRACT: Burning propellant grain studies were conducted on the SUBROC Gas Generator Package (GGP) WOX-5A by use of radiographic techniques. Through the use of an image intensifier and lens system, continuous x-ray motion picture records were obtained of burning propellant grains. During each test, GGP chamber pressure versus time was recorded on an FM instrumentation type tape recorder. Test results confirmed theoretical predictions of propellant grain face contour changes during burning. The radiographic study revealed the extreme usefulness of this method as a tool in developing weapon systems utilizing solid propellants.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NOLTR 62-194 1 November 1962

RADIOGRAPHIC STUDY OF THE BURNING PROPELLANT GRAIN IN THE SUBROC GAS GENERATOR PACKAGE WOX-5A (U)

The radiographic study of the SUBROC gas generator burning propellant grain as described in this report was undertaken by the Operations Division of the Air and Surface Evaluation Department in cooperation with the Nuclear Physics Division of the Physics Research Department. The work was performed under task No. RUSD 2A000/212 1/W030 A0 001.

This report is intended for the information and use of activities engaged in the development of weapons for the Department of Defense. The evaluation techniques described herein are believed of special interest to those concerned with the development of weapons utilizing solid propellants.

R. E. ODENING
Captain, USN
Commander

D D Grantham for/
R. E. GRANTHAM,
By direction

ACKNOWLEDGEMENT

The writer gratefully acknowledges the willing assistance of Mr. Charles Dyer and Mr. Donald Case of the Nuclear Physics Division of this Laboratory. These gentlemen devised, provided, and manned the radiographic instrumentation used in these tests.

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RADIOGRAPHIC STUDY OF THE BURNING PROPELLANT GRAIN IN THE SUBROC GAS GENERATOR PACKAGE WOX-5A (U)

1. INTRODUCTION

1.1 The SUBROC Gas Generator Package (GGP) WOX-5A provides the necessary hot gases required to drive the power turbine of a SUBROC missile. The generator contains an inhibited, insulated dual burn rate, solid propellant grain and a squib initiated ignition system. The steel cylindrical generator case is approximately five inches in diameter, 16 inches in length, and .050 inch in side wall thickness. A cylindrical thermal insulator of .140 inch wall thickness is cemented to the interior of the generator case. Protection of the insulation material from hot gas erosion is provided by a .005 inch wall thickness stainless steel flame shield. The propellant grain, which weighs approximately ten pounds, is pressed into final shape and inhibited with a .095 inch thick inhibitor sheet prior to installation in the generator case. A diagram depicting the above mentioned cross section composition is shown in figure 1.

1.2 Performance firings on the SUBROC GGP WOX-5A have frequently revealed instances where generator chamber pressure gradually drops and recovers with minimum pressure occurring approximately 80 seconds following ignition. This so called "80 second dip" is not serious when generators are fired while conditioned at ambient and 95°F temperatures, but the dip does cause below specification chamber pressure on 25°F firings. Examples of the "80 second dip" are shown in figures 2 and 3 which present data obtained on 23°F and 76°F phase II GGP firings (1). The radiographic study of the burning propellant grain in a SUBROC GGP was initiated in an attempt to discover any abnormal burning characteristics which could cause the above mentioned pressure dip.

2. INSTRUMENTATION

2.1 Each GGP performance test conducted during the radiographic study was instrumented in the same manner as were the NOL phase II GGP's (1). This instrumentation served to record generator chamber pressure versus time (see the instrumentation block diagram, figure 4).

2.2 The first x-ray performance test was conducted with the test set-up shown in figures 5 through 7. As a result of the experience gained in this preliminary test, the remaining tests

were performed with the test set-up shown in figures 8 through 10. Basically, the instrumentation functions as follows:

(a) X-rays from the Norelco TG 260 x-ray machine penetrate the GGP and impinge on the Philips 9 inch image intensifier screen.

(b) The x-ray image is then condensed and intensified on the small output screen of the image intensifier.

(c) A Kodak Fluro Ektar F .075 lens focuses this x-ray image on 35mm black and white negative film in an Automax movie camera operating at 12 frames per second.

2.3 The final test set-up incorporated a means of shifting the position of the GGP while burning and a method of acquiring a common time base between the 35mm film x-ray record and the magnetic tape pressure record. The GGP shift was accomplished by placing the GGP on a lathe bed carriage and shifting the carriage when desired by use of a pulley and line (see figure 9). Timing marks on the 35mm film were obtained by use of a rotating lead disc containing three equally spaced holes which align one at a time with a fixed single hole in a lead back-up plate. Consequently, the x-rays penetrated the lead barrier each two seconds as the disc was driven at 10 rpm resulting in timing marks being recorded on the film. Establishment of a common time base on both the film and magnetic tape records was accomplished by insertion of an electric lamp in the lens system such that when energized, the light would fog the 35mm frames on the film. As a result, the lamp could be turned on for about a minute immediately preceding each test and turned off a known time (approximately five seconds) prior to ignition of the generator thus providing a time zero on the film record. Since the GGP ignition pulse and timing trace were both recorded on the magnetic tape, a common time base could now be established for each run.

2.4 Shielding of the image intensifier by lead and steel sheet was required to prevent overexposure due to x-rays impinging the image intensifier without passing through the gas generator. Also, each gas generator had to be degaussed prior to test to prevent adverse magnetic effects on the image intensifier. Identification of the film records was obtained by the use of lead identification numbers taped to a steel strip on the top of each GGP.

3. TEST RESULTS

3.1 One gas generator package (GGP serial 209 of phase II vintage) was fired using the preliminary x-ray test set-up as

shown in figures 5 through 7. Figure 11 presents the pressure-time data for this test from which a slight "80 second dip" is discernible. The x-ray pictures, which were only taken during about 100 seconds of burn time, revealed an essentially flat burn face during the dip. No film time zero was available for this test and timing had to be estimated using the inaccurate camera frame speed. Also, since the field of the image intensifier did not permit entire coverage of the complete grain, both the first few seconds and the last quarter of the run were not recorded on film. However, this test did prove the feasibility of studying a burning gas generator propellant grain by the use of x-ray techniques involving motion pictures.

3.2 As a result of the above mentioned test, three additional GGP's were made available for radiographic burn face study. With the addition of film timing and the ability to shift position of the GGP during test, GGP serial 222 (Propellant Batch Number L1020R/BL 282) was fired using the test set-up shown in figures 8 through 10. The pressure-time data from this run is presented in figure 12. Lamp failure in this run prevented acquisition of a time zero on the film record. However, the grain shift technique seemed to function properly, and the x-ray pictures revealed a change in grain front contour with a near flat contour developing at minimum pressure.

3.3 The remaining two GGP's (Propellant Batch Number L1020R/BL 282) were tested as follows: GGP serial 219 was fired at ambient temperature ($\sim$70°F) and GGP serial 224 was fired at approximately 27°F. Figures 13 and 14 show the pressure-time data for these two tests. Prints made from the 35mm negative film taken during the last two firings are shown in figures 15 through 24. These prints reveal the same burn face contour change in both tests, the only difference being in the rate of contour change, i.e. the contour changes slower in the 27°F cold firing. Again, the minimum pressures seemed to be directly related to flat burn face contours. Progression of the burning propellant grain at its upper surface and regression at its lower surface was evident during the later portion of the 27°F firing. This "S" surface condition was probably due to the inherent increase in skin temperature on the top of a burning GGP over that on the bottom. This temperature differential would tend to increase the burn rate at the top of the grain and decrease the burn rate at the bottom. Lens parallax makes it difficult to judge accurately the shape of the burn face contour. Ideally, the GGP should be programmed in axial movement in such a manner that the burn face always remains stationary at the center of the lens system, thus eliminating this parallax condition. Metal parts present within each generator were found to cloud two specific areas. The perforated metal dome of the igniter hides the extreme forward

end of the grain; however, after five seconds of burning, this obstacle is no longer in the way. A steel weld back-up ring located near the base of the grain also tends to obscure the burning grain face in this area. Variation in x-ray intensity as the grain burns could eliminate these problems, but this would be as difficult a problem as programming the GGP axial motion to eliminate parallax.

3.4 The last three GGP's tested differed from phase II generators in both the propellant blend and the length of the first stage (20 second first stage in lieu of 40 second first stage). The "80 second dip" is not readily noticeable in these last three firings. However, in comparing the 80 second burn face contour of the last three x-ray firings with the first x-ray firing (phase II type which showed the "80 second dip"), no discernible difference could be detected.

4. CONCLUSIONS

4.1 The radiographic study of the burning propellant grain of the SUBROC GGP WOX-5A confirms theoretical predictions of propellant grain face contour changes during burning. No evidence was acquired that could substantiate abnormal or unpredicted burn phenomena. Consequently, the "80 second dip" must be caused by inherent properties of the propellant, such as a high temperature coefficient π_K (sensitivity of the burn rate at constant area ratio to the propellant temperature).

4.2 The radiographic methods used in these tests provide an excellent tool for use in developing weapon systems utilizing solid propellants. During the development of the GGP WOX-5A, high pressure failures were encountered due to flame shield buckling. This pressure anomaly could possibly have been detected at an earlier date if x-ray motion pictures were taken of the burning propellant grain.

REFERENCES

1. R. H. STANGE, PHASE II DEVELOPMENT TESTS PERFORMED ON THE SUBROC GAS GENERATOR PACKAGE WOX-5A, NOLTR 62-181 (1962) (Confidential)

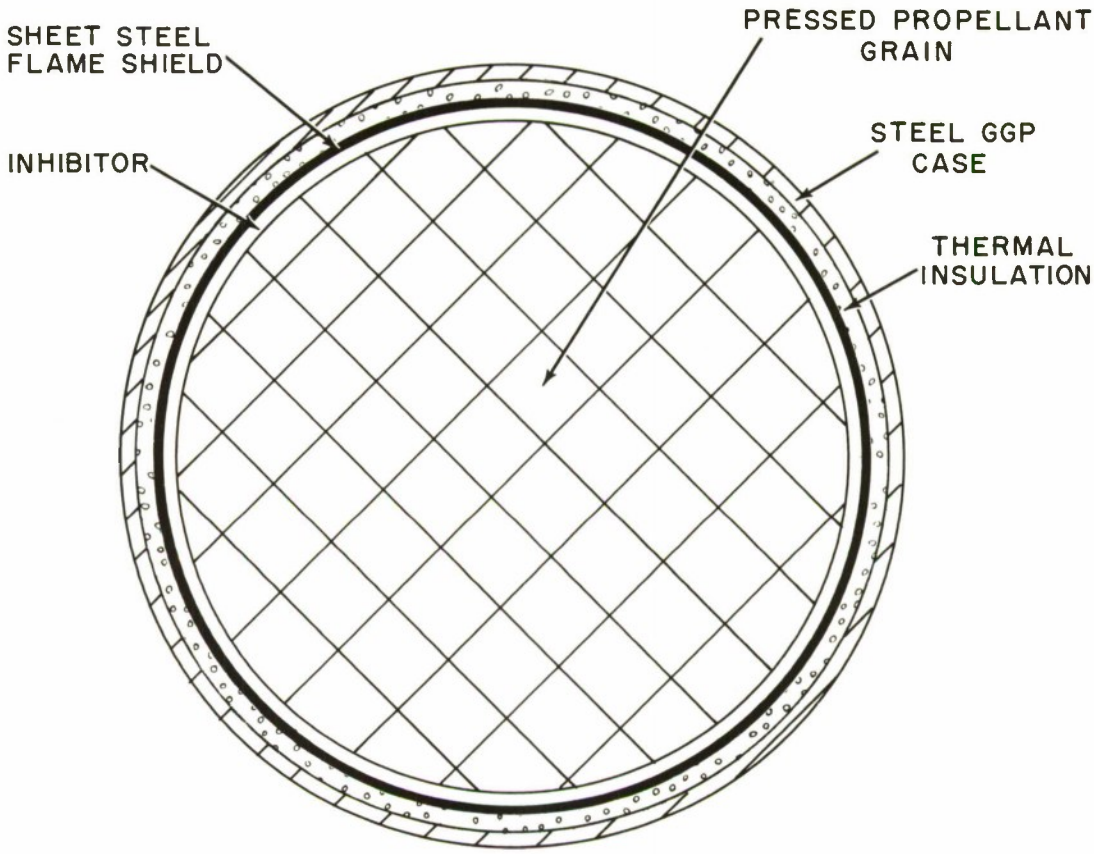


FIG. I GGP CROSS SECTIONAL DIAGRAM

NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

SUEROC GAS GENERATOR PACKAGE WOX-5
PERFORMANCE TEST DATA SHEET

TEST NUMBER 2

SERIAL NO. 123 DATE OF TEST 7/2/62
BATCH NO. BL 268B/271C GRAIN NO. -82
LOT NO. 2 TASK 2.9 DATE LOADED 4/62
DATE GRAIN MFD. 2/62
GENERATOR PRECONDITIONING: L/F VIB-2 AMB.

NOZZLE INFORMATION: NUMBER 3

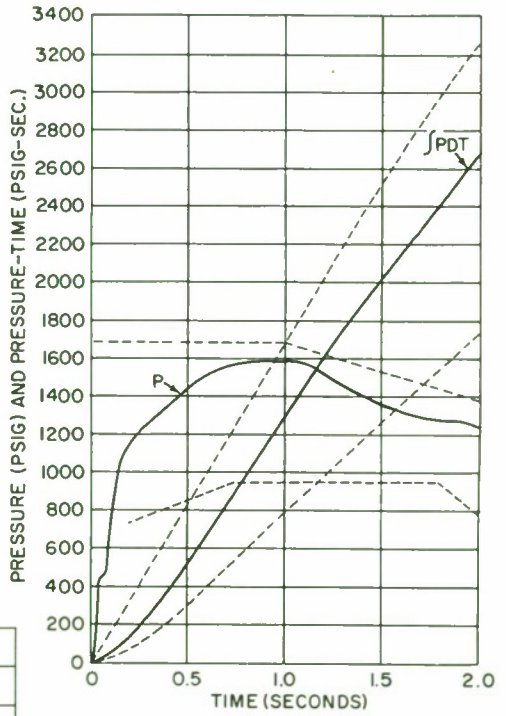
FLOW CHECK	BEFORE FIRING	AFTER FIRING
TEMPERATURE (°F)	76	76
UPSTREAM PRESSURE (PSIG)	50	50
△P (INCHES H_2O)	9.85	8.6

GENERATOR FIRING CONDITIONS:
TEMPERATURE (°F) 76
STATIC [XX] VIBRATING [ ]
WEIGHT BEFORE FIRING 20 LB. 1/2 OZ.
WEIGHT AFTER FIRING 9 LB. 5 OZ.

RESULTS:

ITEM	STAGE I	STAGE II	COMBINED
P MAX. (PSIG)	1590	888	1590
P MIN. (PSIG)	844	743	743
P AVE. (PSIG)	913	779	808
BURN TIME (SEC.)	39	138.5	177.5

REMARKS:
This run was within specs.



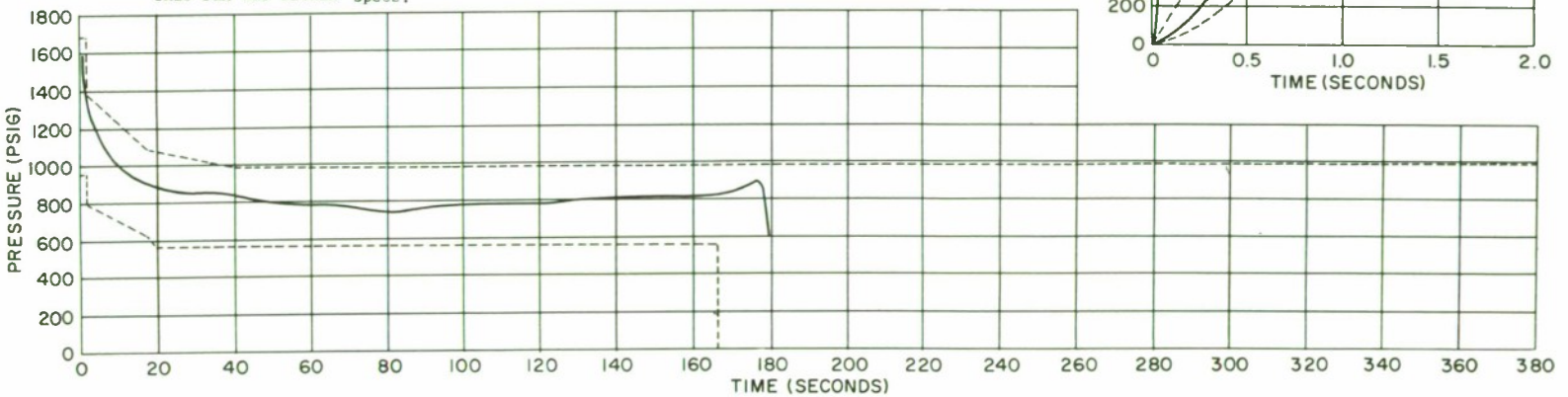


FIG.2 PRESSURE—TIME DATA GGP WOX—5A

NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

SUBROC GAS GENERATOR PACKAGE WOX-5
PERFORMANCE TEST DATA SHEET

TEST NUMBER 11

SERIAL NO. 122 DATE OF TEST 7/18/62
BATCH NO. BL 268B/271C GRAIN NO. -81
LOT NO. 2 TASK 2.9 DATE LOADED 4/62
DATE GRAIN MFD. 2/62
GENERATOR PRECONDITIONING: L/F VIB-2 Amb.
Dropped in package 3 times on each end from 30 inches.

NOZZLE INFORMATION: NUMBER 2

FLOW CHECK	BEFORE FIRING	AFTER FIRING
TEMPERATURE (°F)	80	79
UPSTREAM PRESSURE (PSIG)	50	50
△P (INCHES H_2O)	9.50	4.35

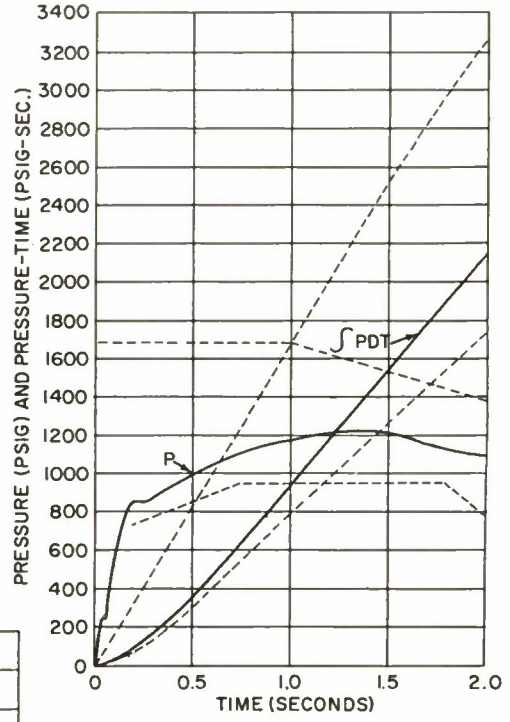
GENERATOR FIRING CONDITIONS:
TEMPERATURE (°F) 23
STATIC [XX] VIBRATING [ ]
WEIGHT BEFORE FIRING 20 LB. 0 OZ.
WEIGHT AFTER FIRING 9 LB. 3 1/2 OZ.

RESULTS:

ITEM	STAGE I	STAGE II	COMBINED
P MAX. (PSIG)	1210	785	1210
P MIN. (PSIG)	690	527	527
P AVE. (PSIG)	782	610	645
BURN TIME (SEC.)	51	196	247

REMARKS:

This GGP was fired cold in lieu of ambient as previously scheduled. The pressure dropped a little out of spec between 70 and 140 seconds. This run may have satisfactorily operated a SUBROC APU.



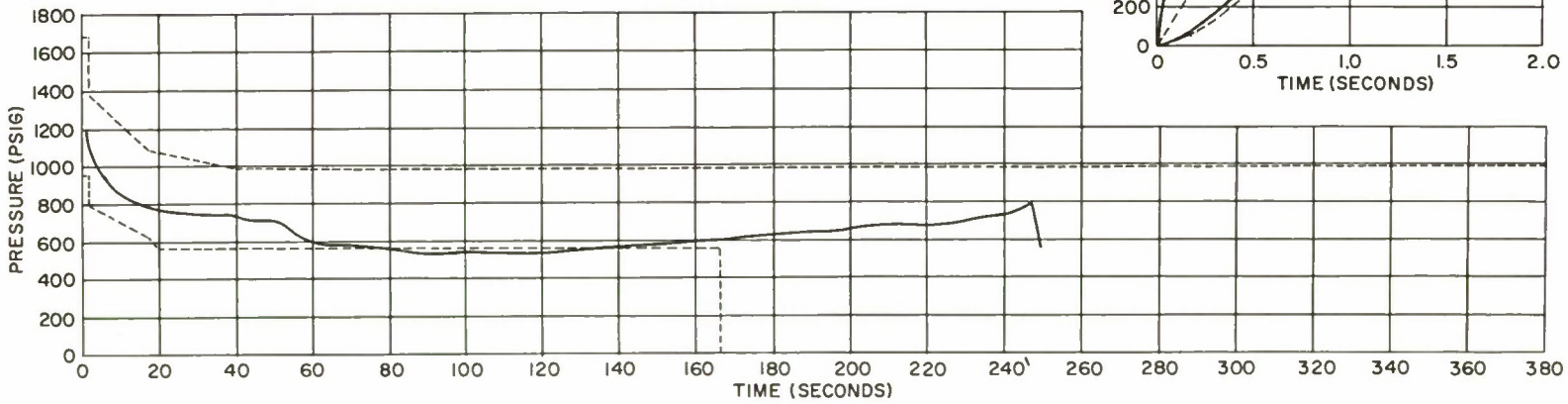


FIG. 3 PRESSURE — TIME DATA GGP WOX—5A

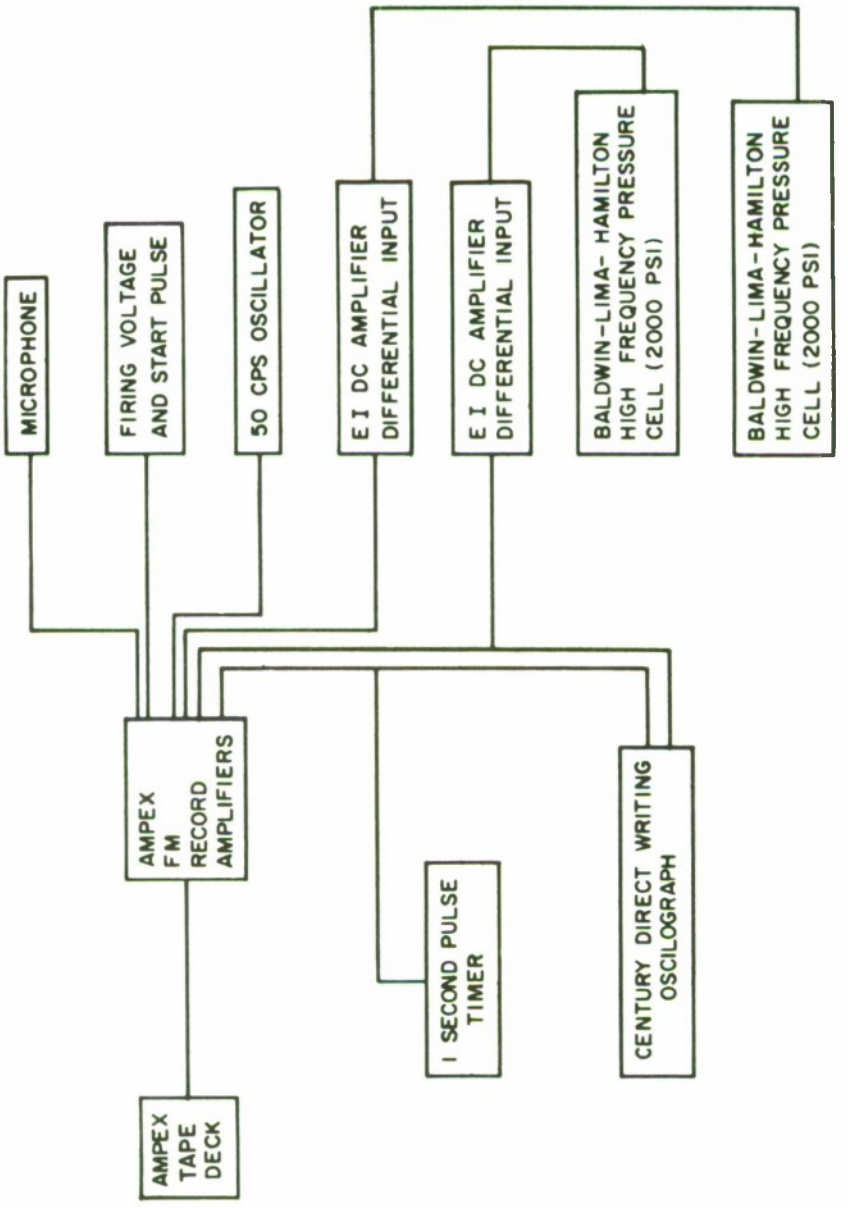


FIGURE 4 INSTRUMENTATION BLOCK DIAGRAM

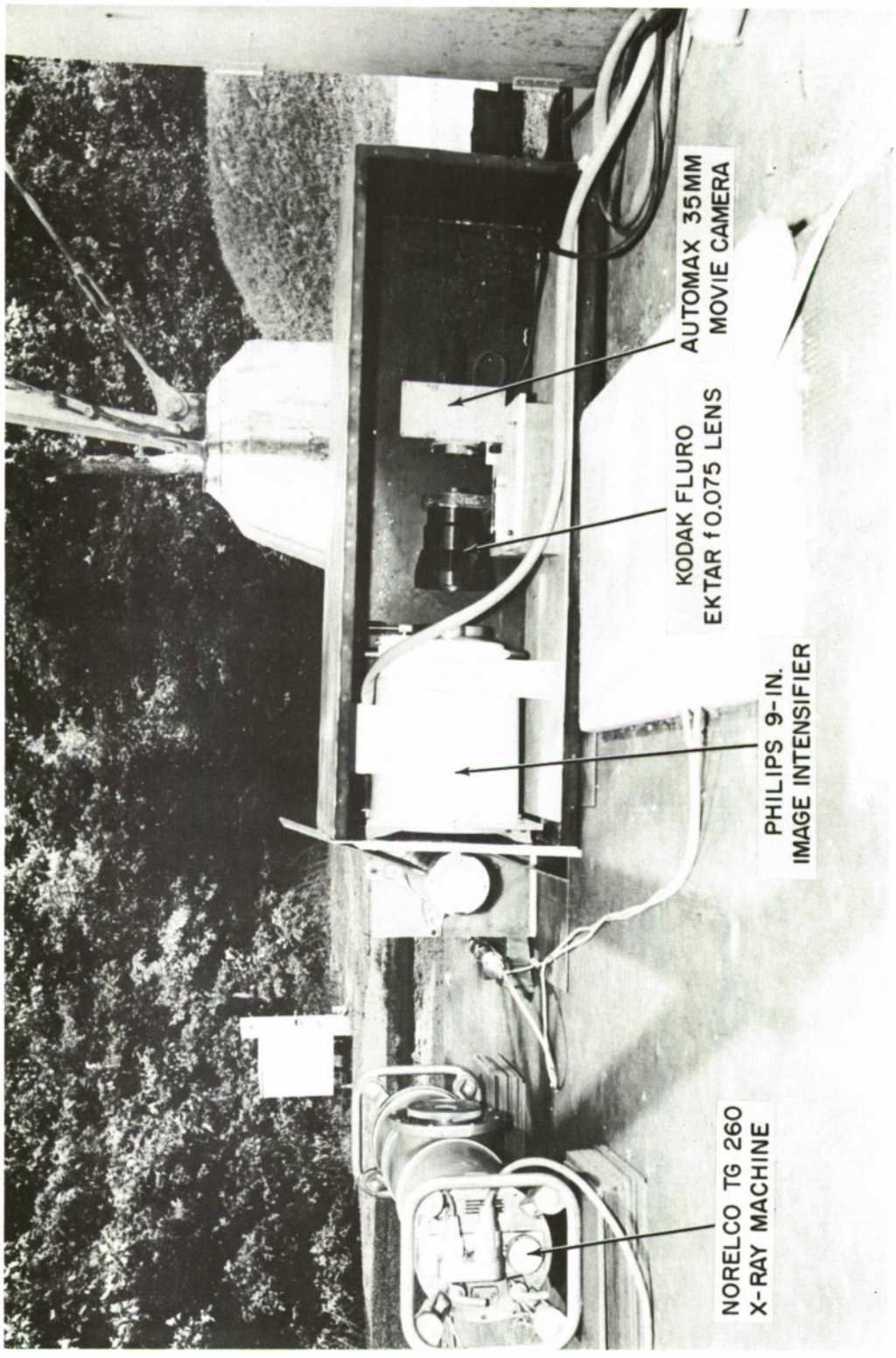


FIG. 5 PRELIMINARY X-RAY TEST SET UP (VIEW I)

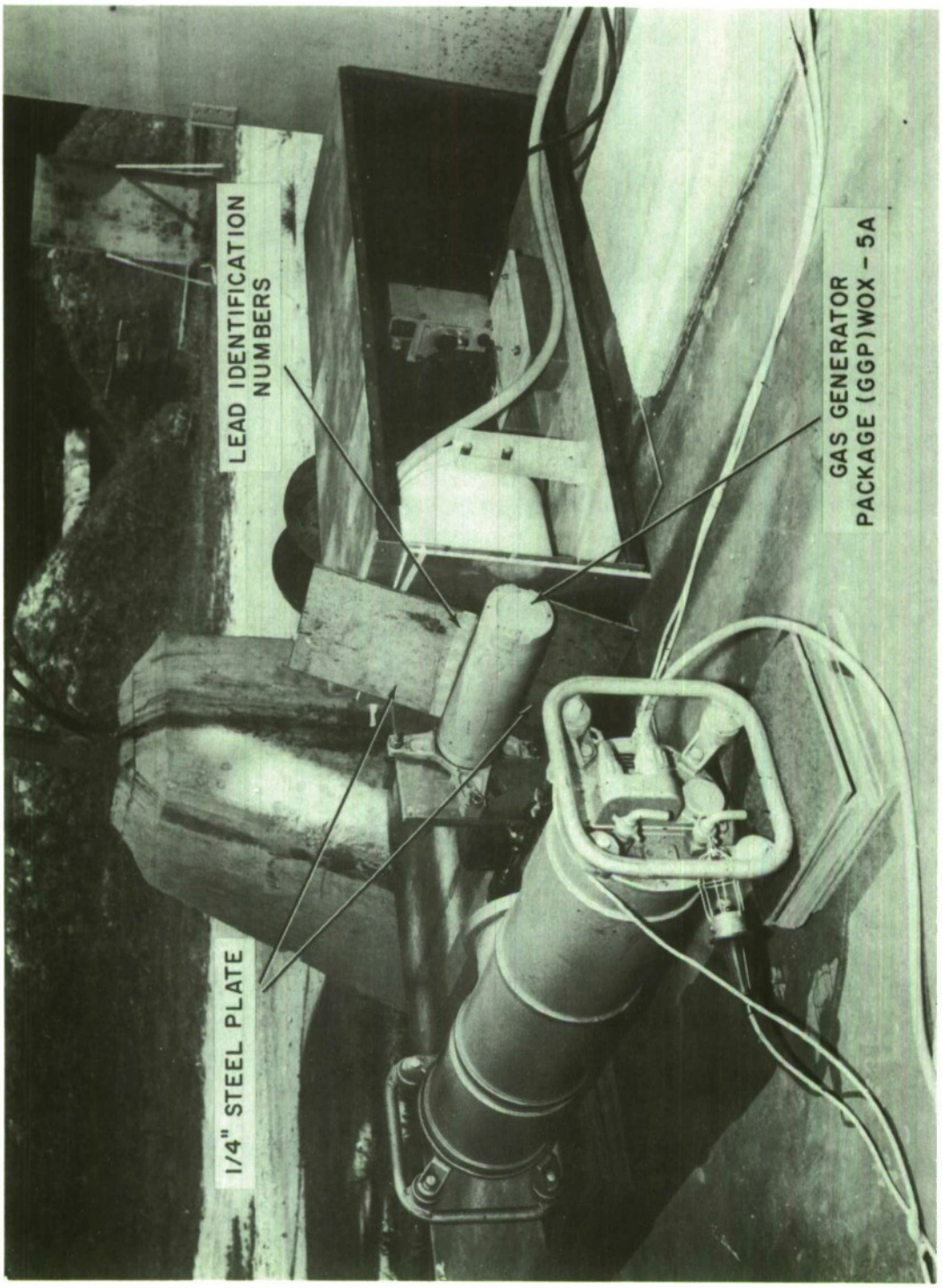


FIG. 6 PRELIMINARY X-RAY TEST SET UP (VIEW 2)

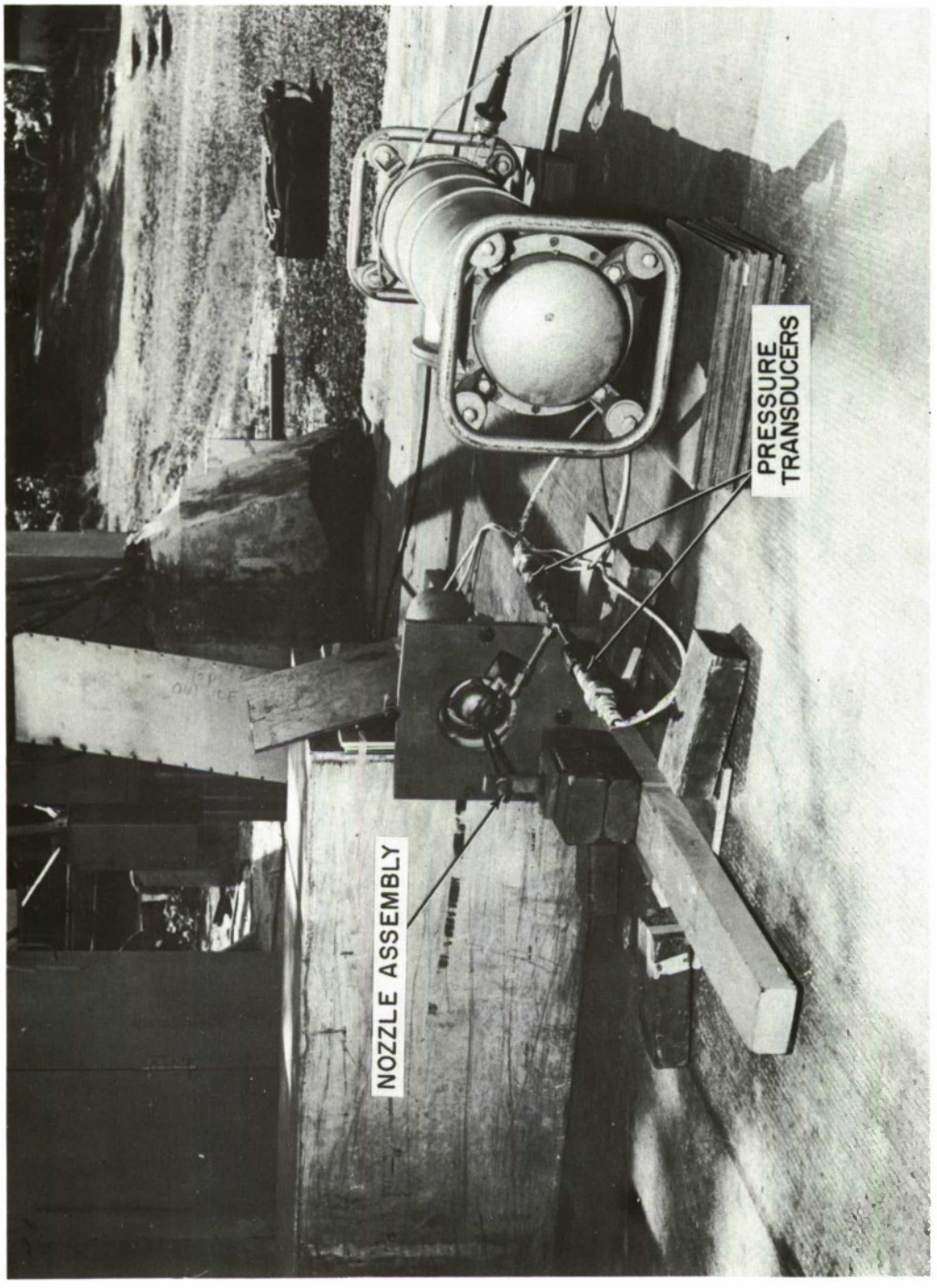


FIG. 7 PRELIMINARY X-RAY TEST SET UP (VIEW 3)

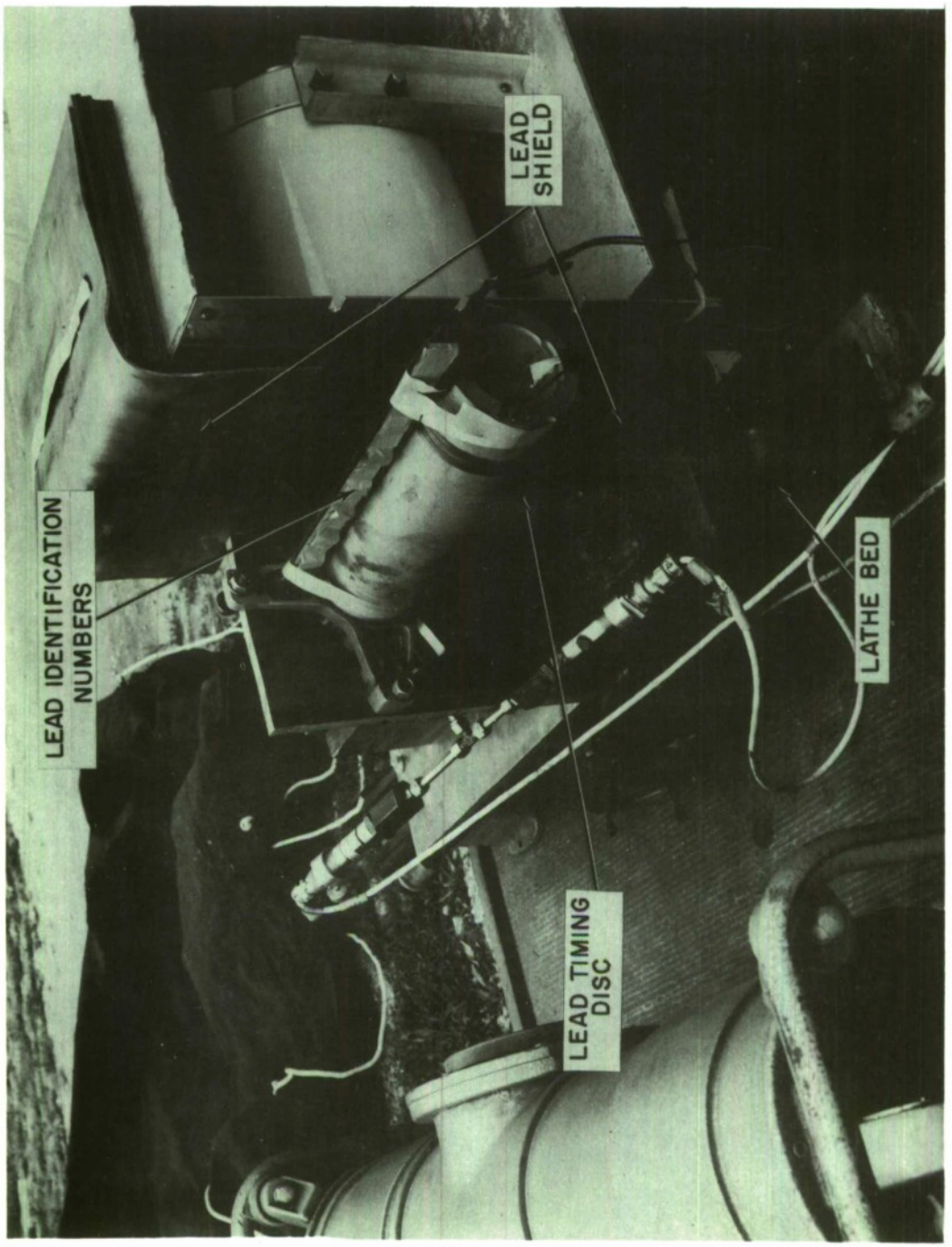


FIG. 8 FINAL X-RAY TEST SET UP (VIEW I)

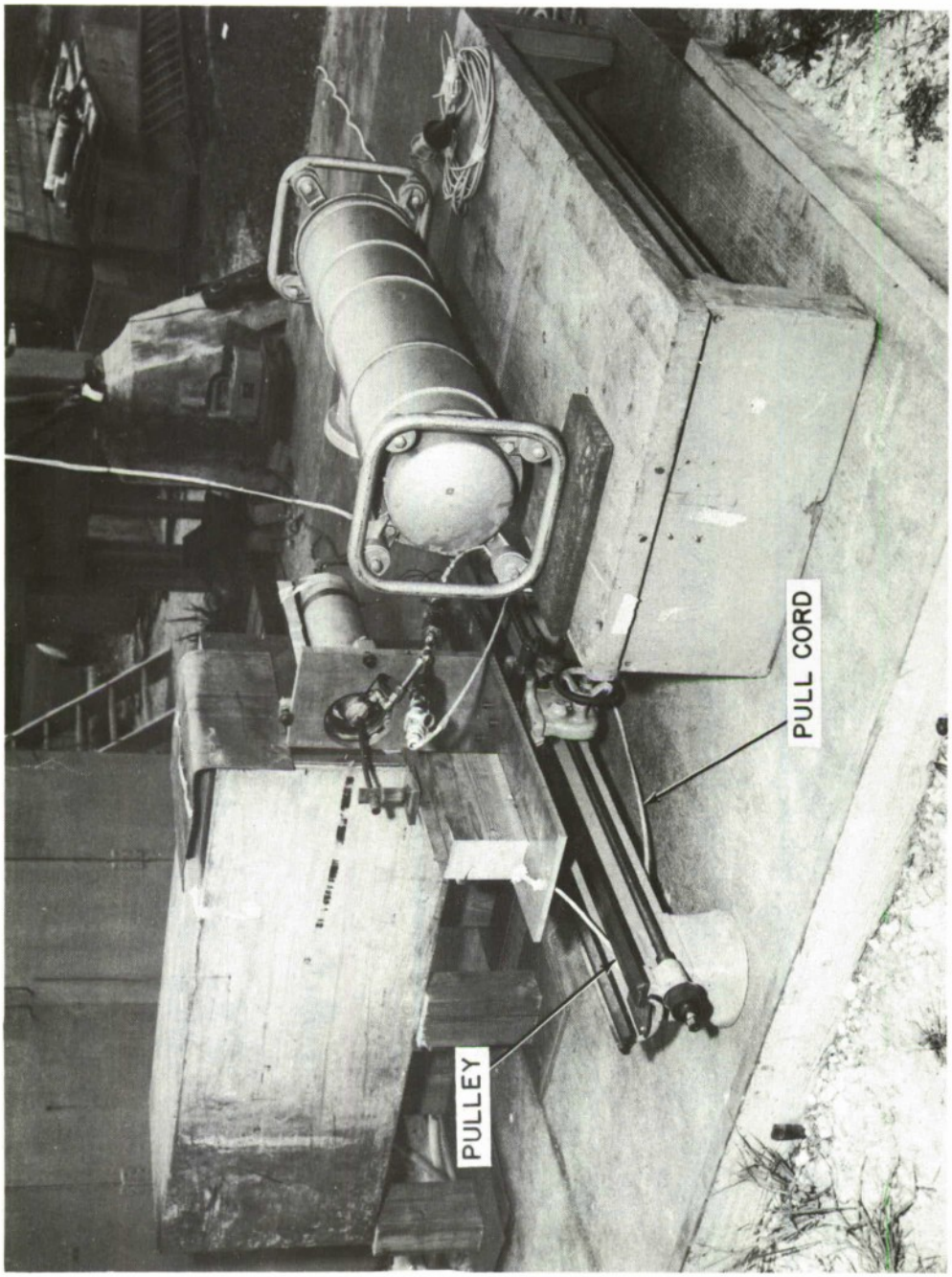


FIG. 9 FINAL X-RAY TEST SET UP (VIEW 2)

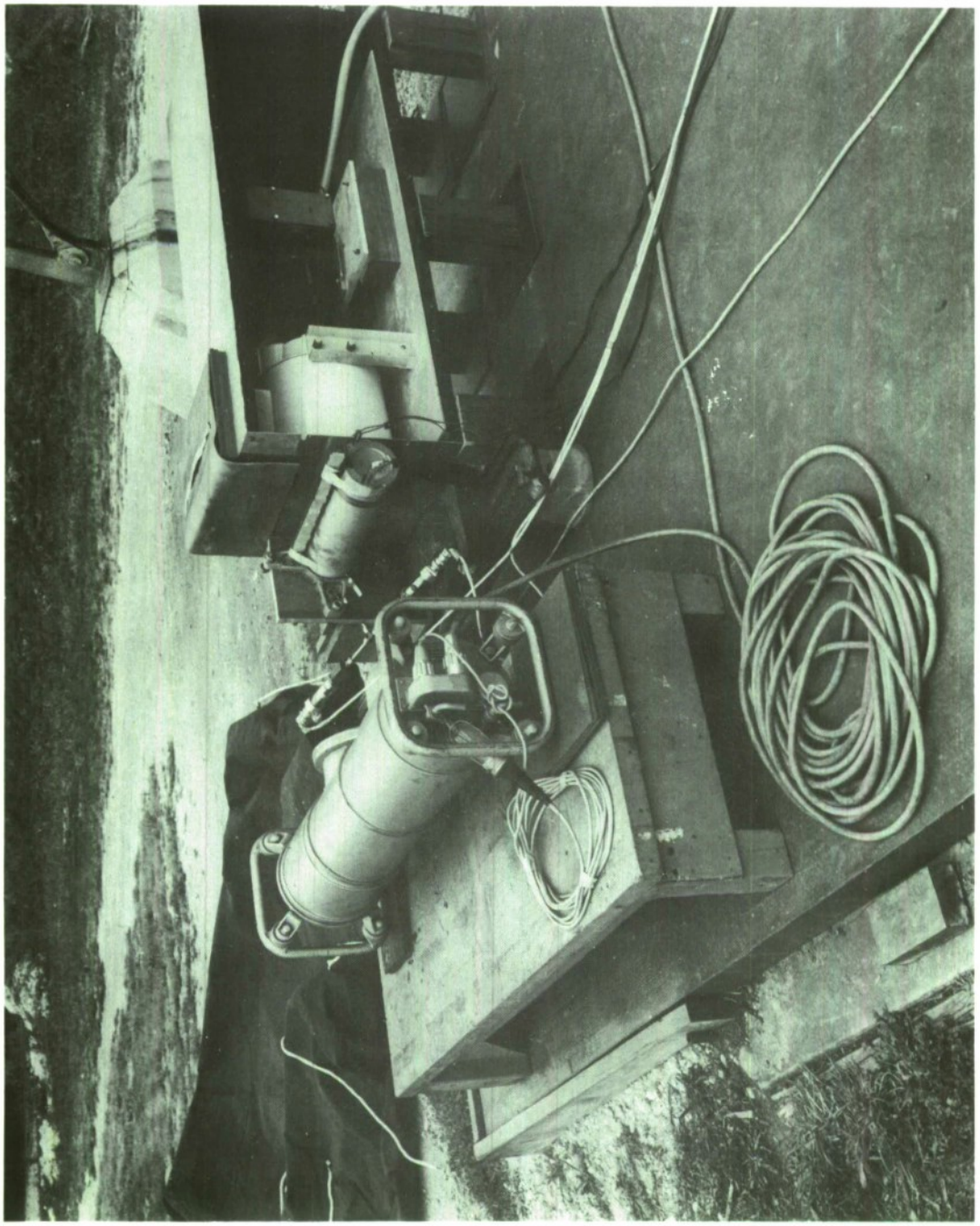


FIG. 10 FINAL X-RAY TEST SET UP (VIEW 3)

NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

SUEROC GAS GENERATOR PACKAGE WOX-5
PERFORMANCE TEST DATA SHEET

TEST NUMBER 14

SERIAL NO. 209 DATE OF TEST 7/26/62
BATCH NO. BL268B/271C GRAIN NO. 78
LOT NO. 3 Task 2.12 DATE LOADED 4/62
DATE GRAIN MFD. 2/62
GENERATOR PRECONDITIONING: None

NOZZLE INFORMATION: NUMBER 6

FLOW CHECK	BEFORE FIRING	AFTER FIRING
TEMPERATURE (°F)	80	
UPSTREAM PRESSURE (PSIG)	50	
△P (INCHES H_2O)	9.5	

GENERATOR FIRING CONDITIONS:

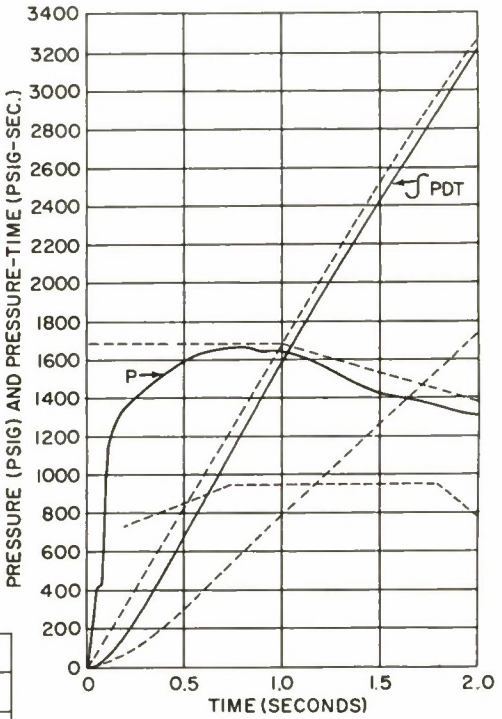
TEMPERATURE (°F) 75
STATIC [X] VIBRATING [ ]
WEIGHT BEFORE FIRING _____ LB. _____ OZ.
WEIGHT AFTER FIRING _____ LB. _____ OZ.

RESULTS:

ITEM	STAGE I	STAGE II	COMBINED
P MAX. (PSIG)	1662	901	1662
P MIN. (PSIG)	921	813	813
P AVE. (PSIG)	1032	842	882
BURN TIME (SEC.)	38.5	137.5	176

REMARKS:

X-ray motion pictures were taken of the burning propellant grain to study the burn face.



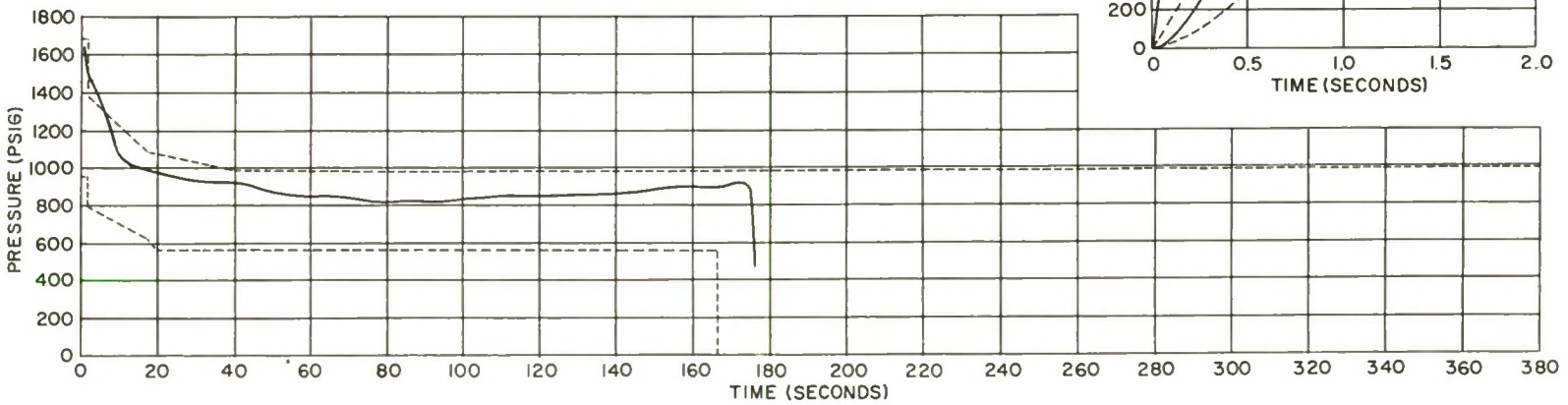


FIG. 11 PRESSURE-TIME DATA GGP WOX-5A

NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

SUBROC GAS GENERATOR PACKAGE WOX-5
PERFORMANCE TEST DATA SHEET

TEST NUMBER 15

SERIAL NO. 222 DATE OF TEST 8/10/62
BATCH NO. L1020R/BL282 GRAIN NO. 32
LOT NO. 5 Task 2.12 DATE LOADED 6/62
DATE GRAIN MFD. 6/62
GENERATOR PRECONDITIONING: None

NOZZLE INFORMATION: NUMBER 1

FLOW CHECK	BEFORE FIRING	AFTER FIRING
TEMPERATURE (°F)	78	
UPSTREAM PRESSURE (PSIG)	50	
△P (INCHES H_2O)	9.7	

GENERATOR FIRING CONDITIONS:

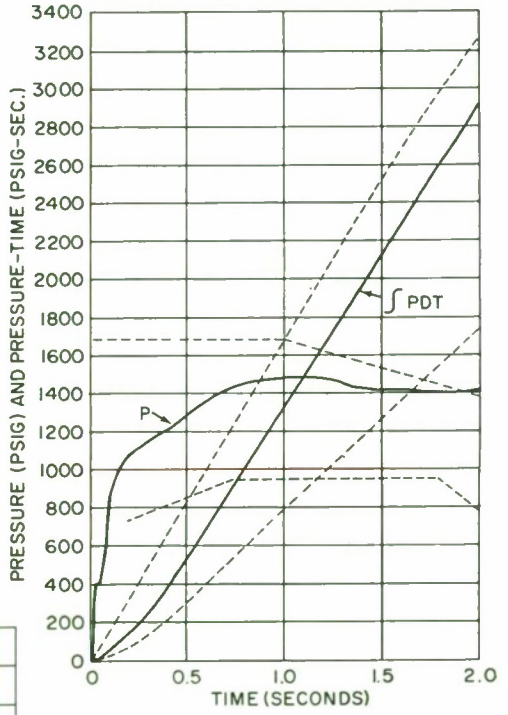
TEMPERATURE (°F) 70
STATIC [X] VIBRATING [ ]
WEIGHT BEFORE FIRING ____LB. ____OZ.
WEIGHT AFTER FIRING ____LB. ____OZ.

RESULTS:

ITEM	STAGE I	STAGE II	COMBINED
P MAX. (PSIG)	1480	906	1480
P MIN. (PSIG)	1090	796	796
P AVE. (PSIG)	1175	839	876
BURN TIME (SEC.)	19	161.5	181.5

REMARKS:

X-ray motion pictures were taken of the burning propellant grain to study the burn face.



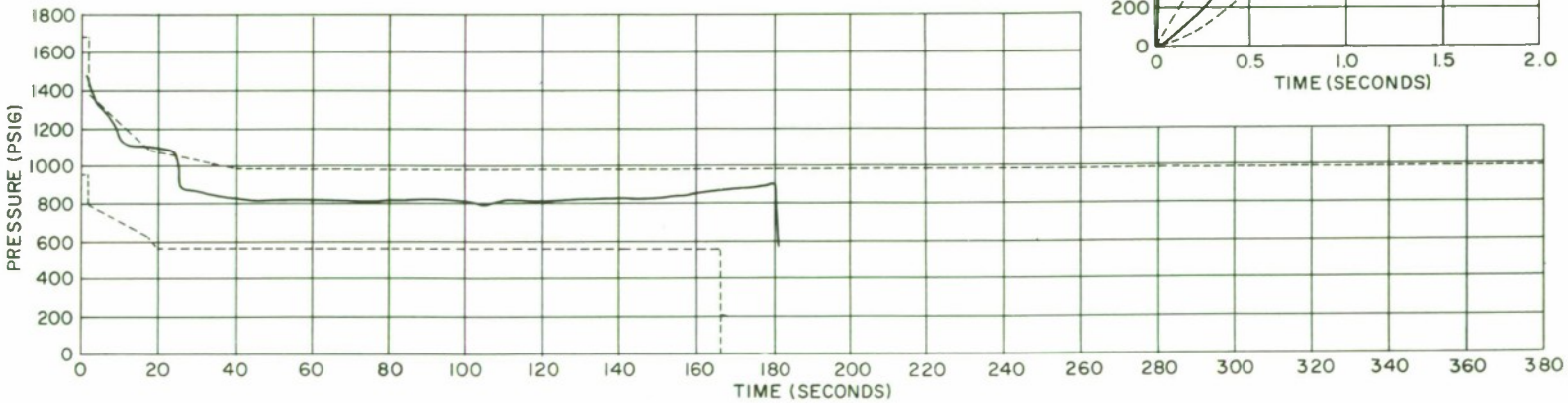


FIG. 12 PRESSURE-TIME DATA GGP WOX-5A

NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

SUBROC GAS GENERATOR PACKAGE WOX-5
PERFORMANCE TEST DATA SHEET

TEST NUMBER 16

SERIAL NO. 219 DATE OF TEST 8/10/62
BATCH NO. L1020R/BL282 GRAIN NO. 29
LOT NO. 5 Task 2.12 DATE LOADED 6/62
DATE GRAIN MFD. 6/62
GENERATOR PRECONDITIONING: None

NOZZLE INFORMATION: NUMBER 4

FLOW CHECK	BEFORE FIRING	AFTER FIRING
TEMPERATURE (°F)	76	
UPSTREAM PRESSURE (PSIG)	50	
△P (INCHES H_2O)	9.75	

GENERATOR FIRING CONDITIONS:

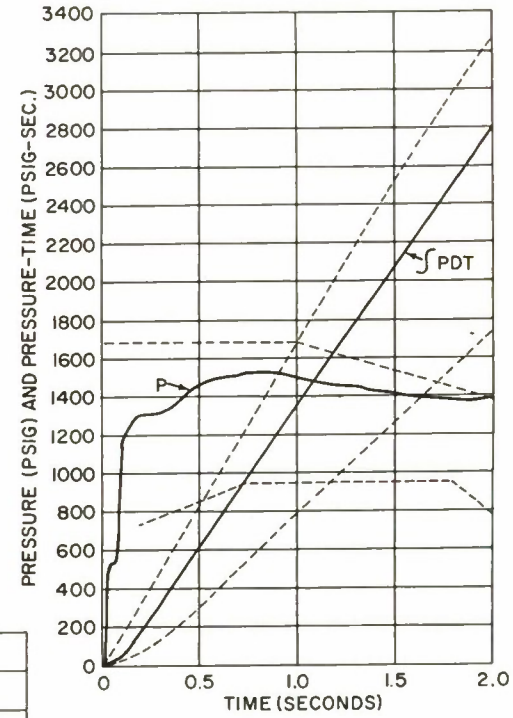
TEMPERATURE (°F) 70
STATIC [X] VIBRATING [ ]
WEIGHT BEFORE FIRING _____LB. _____OZ.
WEIGHT AFTER FIRING _____LB. _____OZ.

RESULTS:

ITEM	STAGE I	STAGE II	COMBINED
P MAX. (PSIG)	1525	909	1525
P MIN. (PSIG)	1123	803	803
P AVE. (PSIG)	1175	864	895
BURN TIME (SEC.)	19.5	161.7	181.2

REMARKS:

X-ray motion pictures were taken of the burning propellant grain to study the burn face.



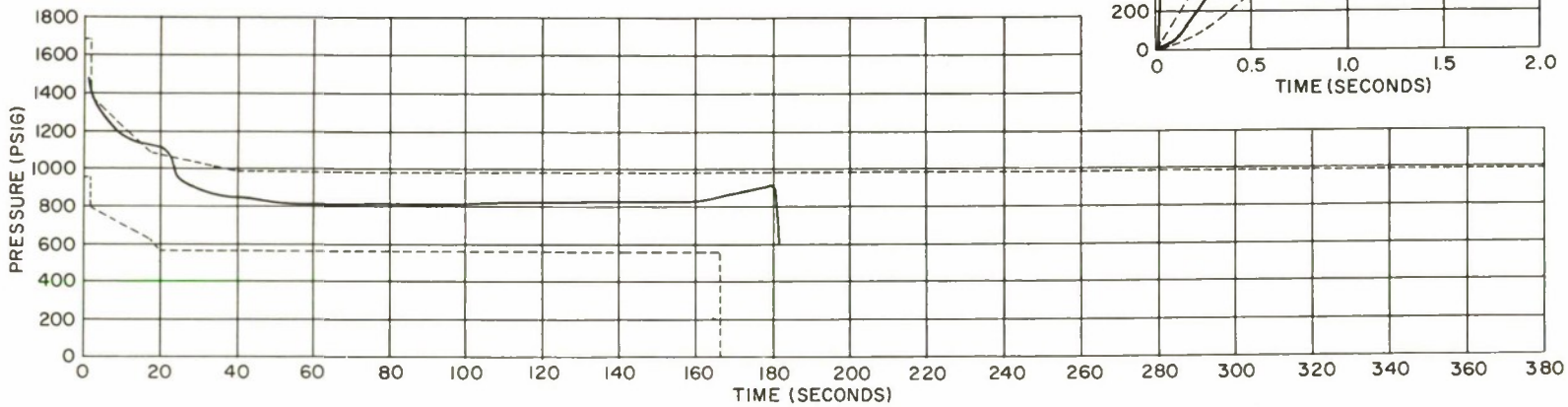


FIG. 13 PRESSURE-TIME DATA GGP WOX-5A

NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

SUBROC GAS GENERATOR PACKAGE WOX-5
PERFORMANCE TEST DATA SHEET

TEST NUMBER 17

SERIAL NO. 224 DATE OF TEST 8/10/62
BATCH NO. L1020R/BL282 GRAIN NO. 34
LOT NO. 5 Task 2.12 DATE LOADED 6/62
DATE GRAIN MFD. 6/62
GENERATOR PRECONDITIONING: None

NOZZLE INFORMATION: NUMBER 3

FLOW CHECK	BEFORE FIRING	AFTER FIRING
TEMPERATURE (°F)	76	
UPSTREAM PRESSURE (PSIG)	50	
△P (INCHES H_2O)	9.75	

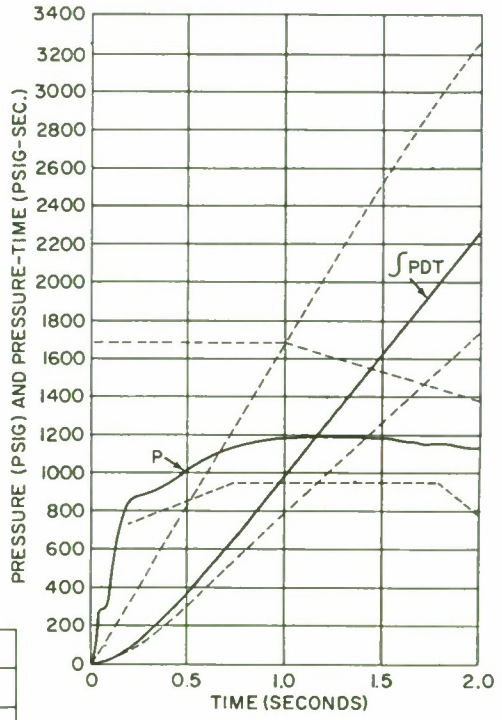
GENERATOR FIRING CONDITIONS:
TEMPERATURE (°F) 27
STATIC [X] VIBRATING [ ]
WEIGHT BEFORE FIRING ____LB. ____OZ.
WEIGHT AFTER FIRING ____LB. ____OZ.

RESULTS:

ITEM	STAGE I	STAGE II	COMBINED
P MAX. (PSIG)	1205	714	1205
P MIN. (PSIG)	925	621	621
P AVE. (PSIG)	1034	658	686
BURN TIME (SEC.)	19.5	215.9	235.4

REMARKS:

X-ray motion pictures were taken of the burning propellant grain to study the burn face.



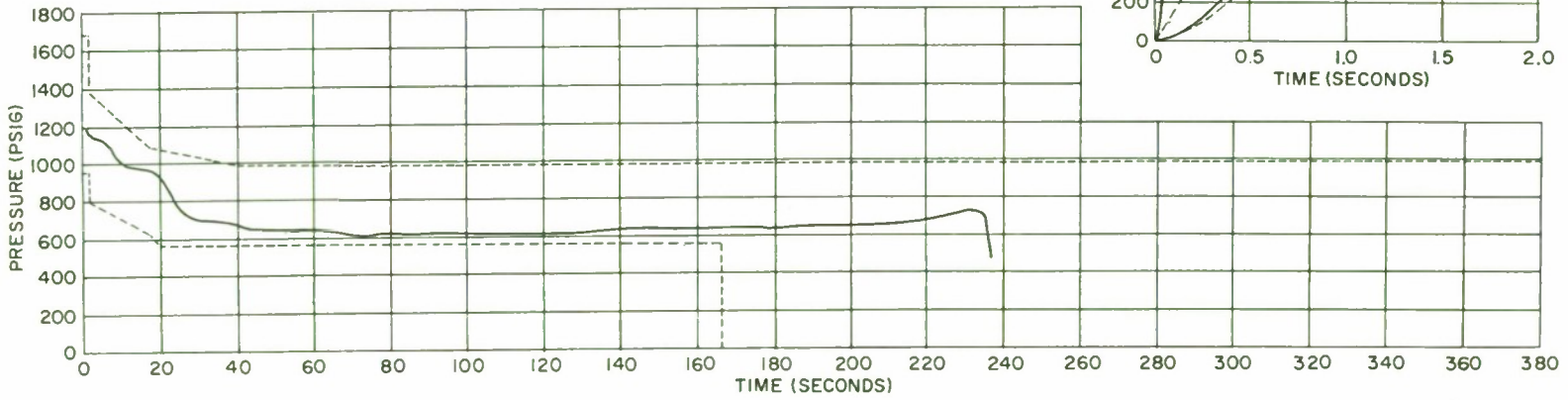
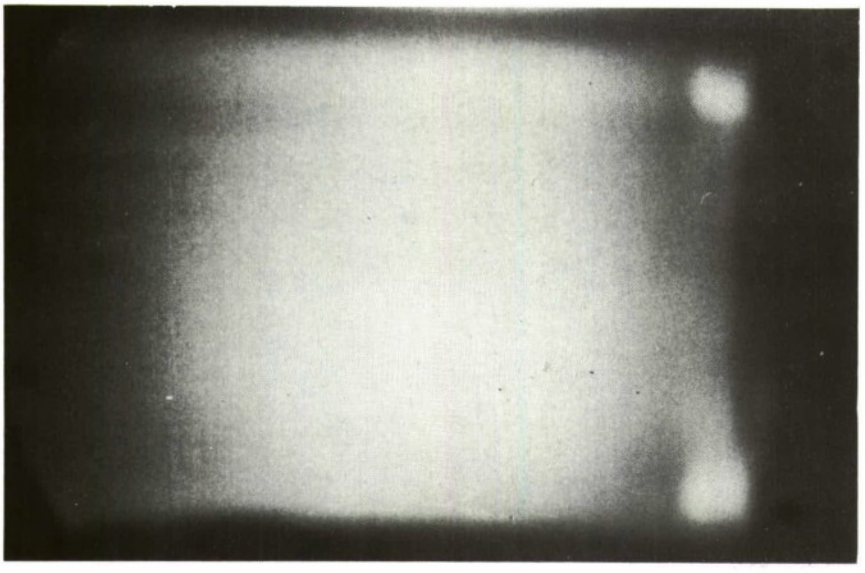


FIG. 14 PRESSURE-TIME DATA GGP WOX-5A



FRAME 1

T = 0 SEC

P = 0 PSIG

FRAME 2

T = 5 SEC

P = 1290 PSIG

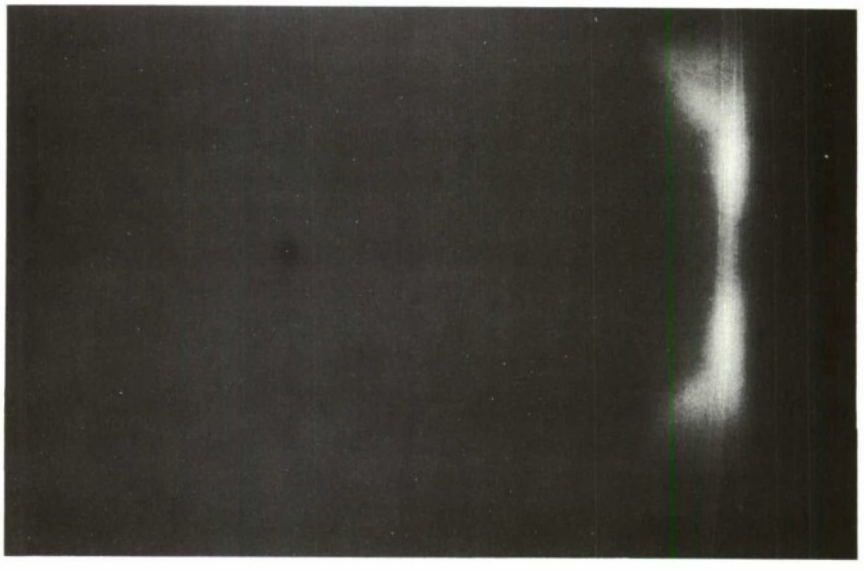
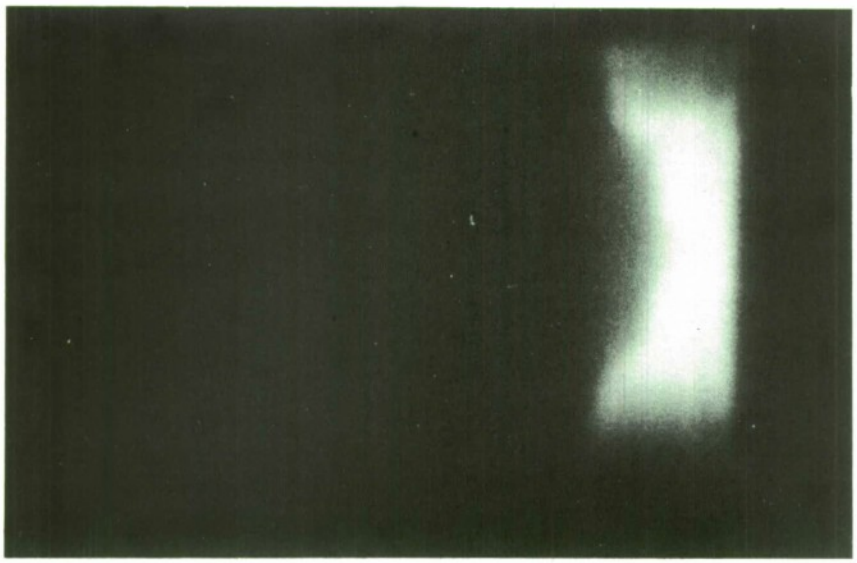


FIG. 15 X-RAY PICTURES OF GGP SERIAL NO. 219
FIRED AT AMBIENT TEMPERATURE (70°F)



FRAME 3

T = 10 SEC

P = 1158 PSIG

FRAME 4

T = 20 SEC

P = 1123 PSIG

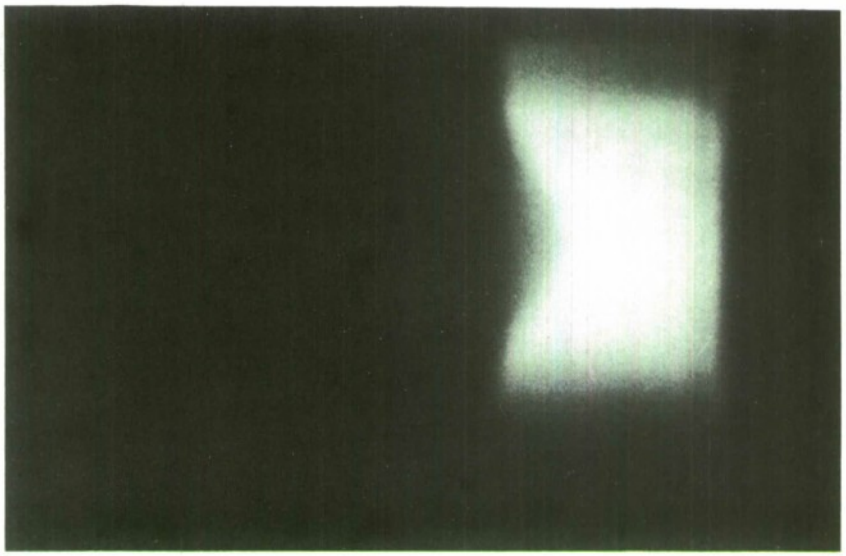
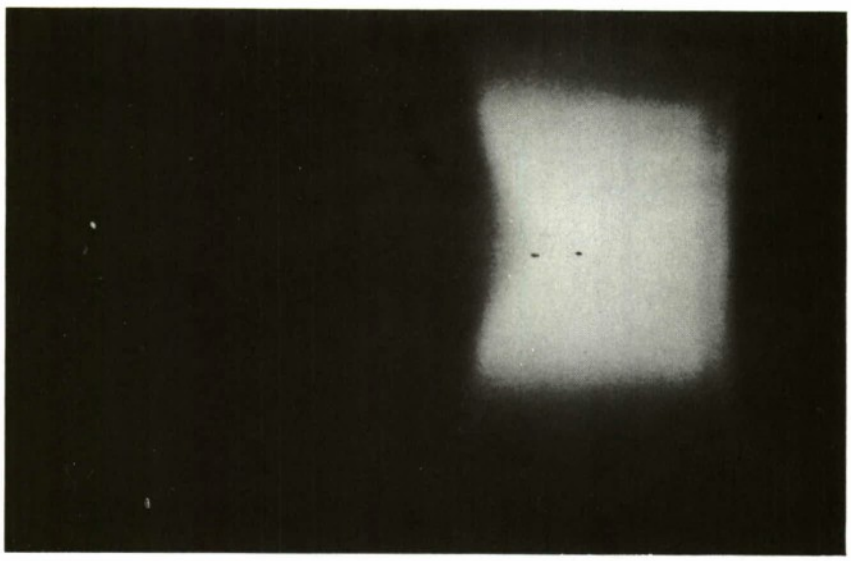


FIG. 16 X-RAY PICTURES OF GGP SERIAL NO. 219
FIRED AT AMBIENT TEMPERATURE (70°F)



FRAME 5

T = 25 SEC

P = 925 PSIG

FRAME 6

T = 50 SEC

P = 813 PSIG

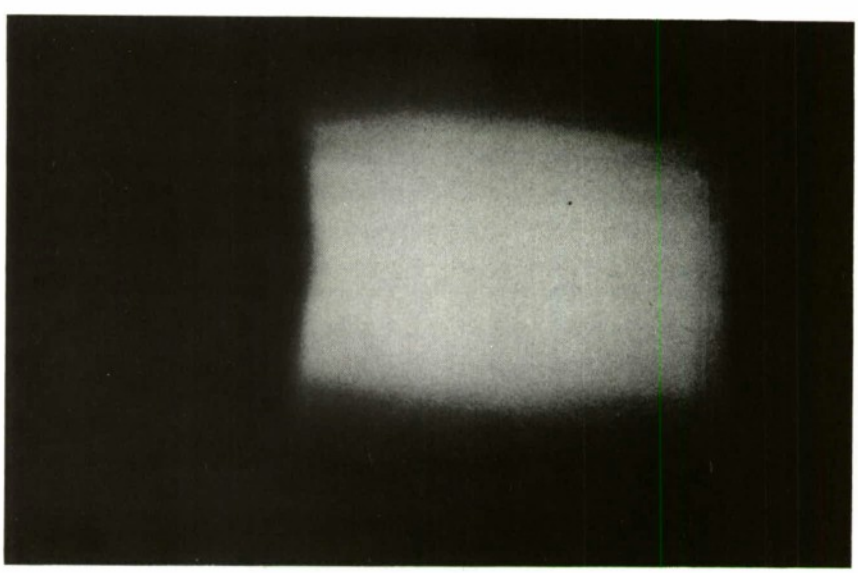
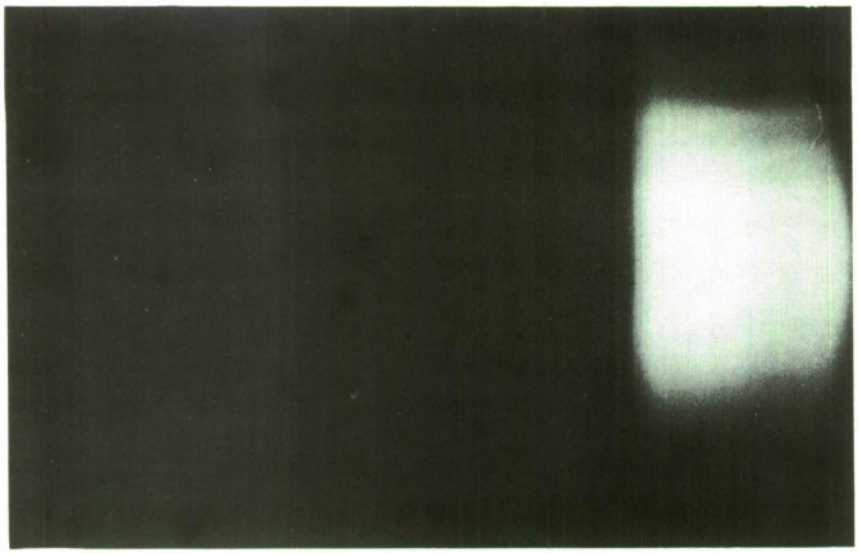


FIG. 17 X-RAY PICTURES OF GGP SERIAL NO. 219 FIRED AT AMBIENT TEMPERATURE (70°F)



FRAME 7

T = 100 SEC

P = 818 PSIG

NOTE: THE GGP WAS SHIFTED FORWARD PRIOR TO FRAME 7.

FRAME 8

T = 150 SEC

P = 829 PSIG

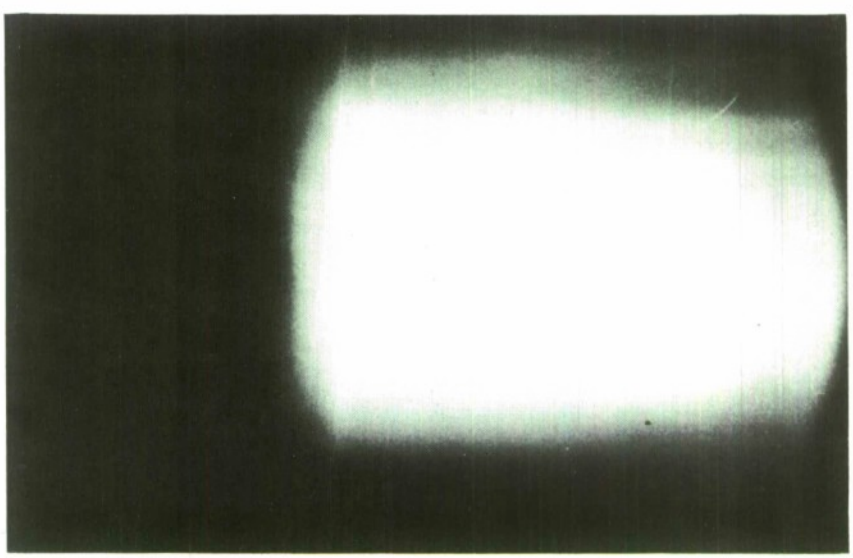
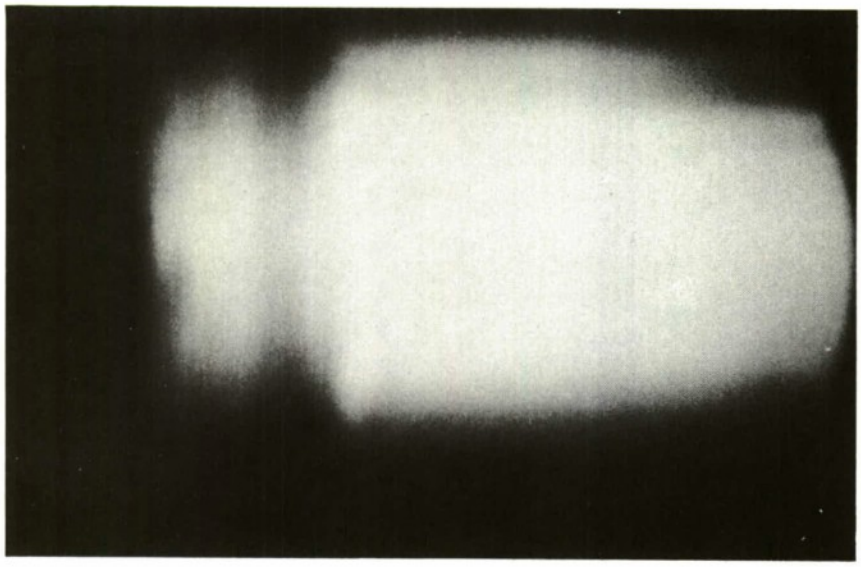


FIG. 18 X-RAY PICTURES OF GGP SERIAL NO. 219 FIRED AT AMBIENT TEMPERATURE (70°F)



FRAME 9

T = 170 SEC

P = 866 PSIG

FRAME 10

T = 180 SEC

P = 909 PSIG

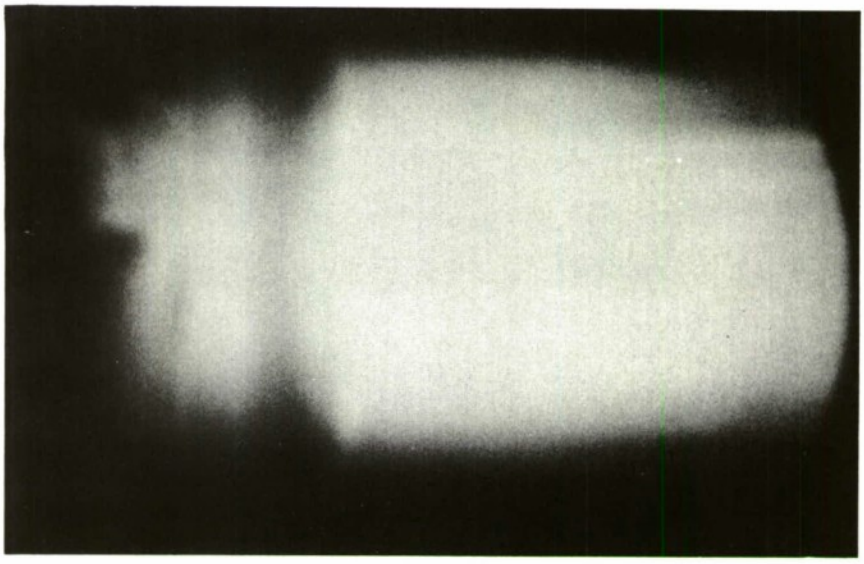
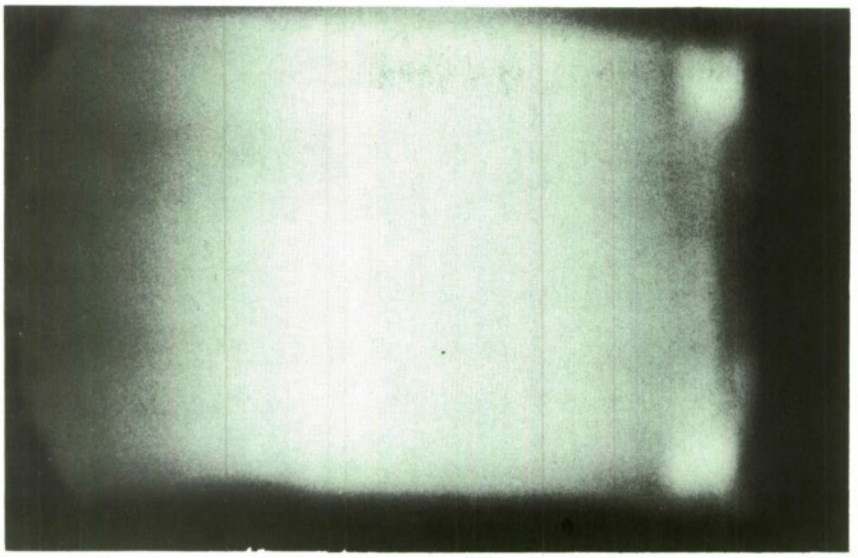


FIG. 19 X-RAY PICTURES OF GGP SERIAL NO. 219
FIRED AT AMBIENT TEMPERATURE (70°F)



FRAME 1

T = 0 SEC

P = 0 PSIG

FRAME 2

T = 5 SEC

P = 1135 PSIG

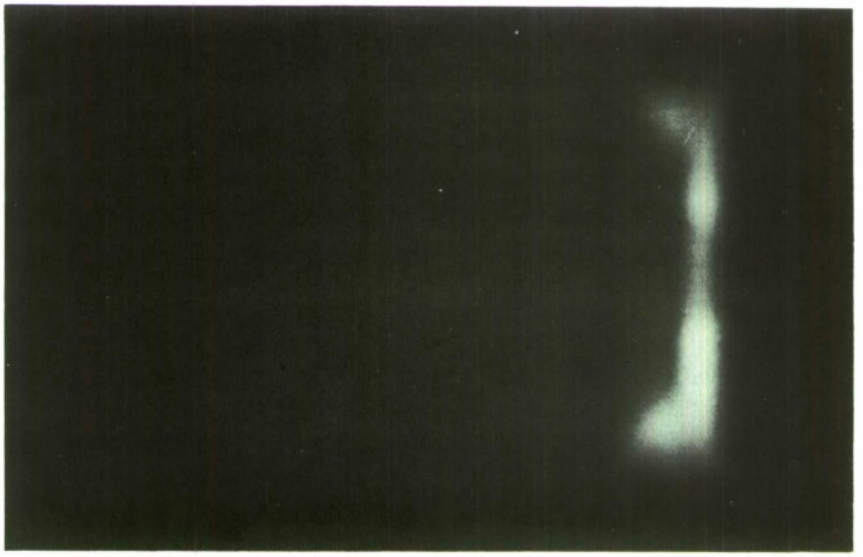
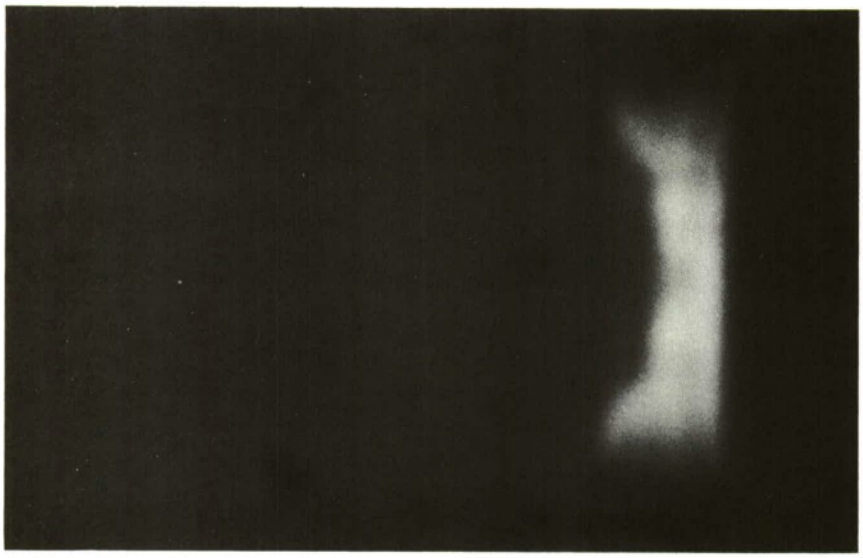


FIG. 20 X-RAY PICTURES OF GGP SERIAL NO. 224
FIRED AT 27°F



FRAME 3

T = 10 SEC

P = 984 PSIG

FRAME 4

T = 20 SEC

P = 925 PSIG

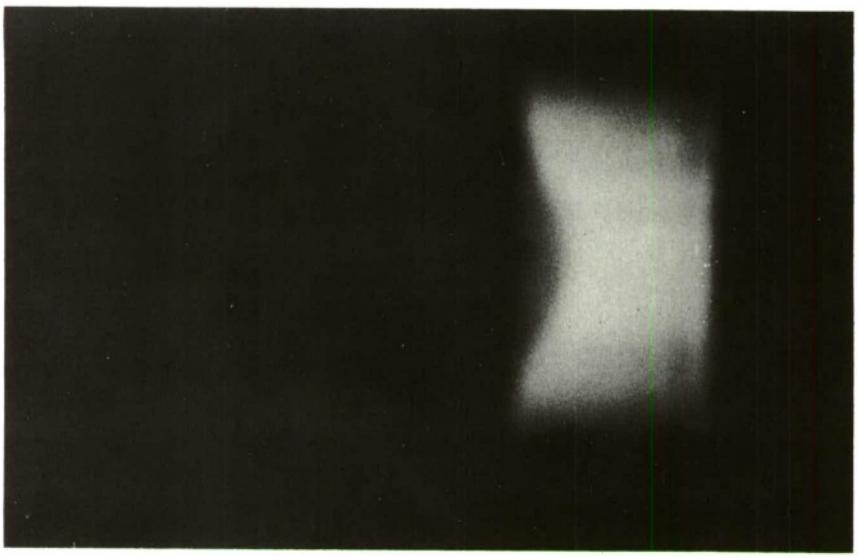
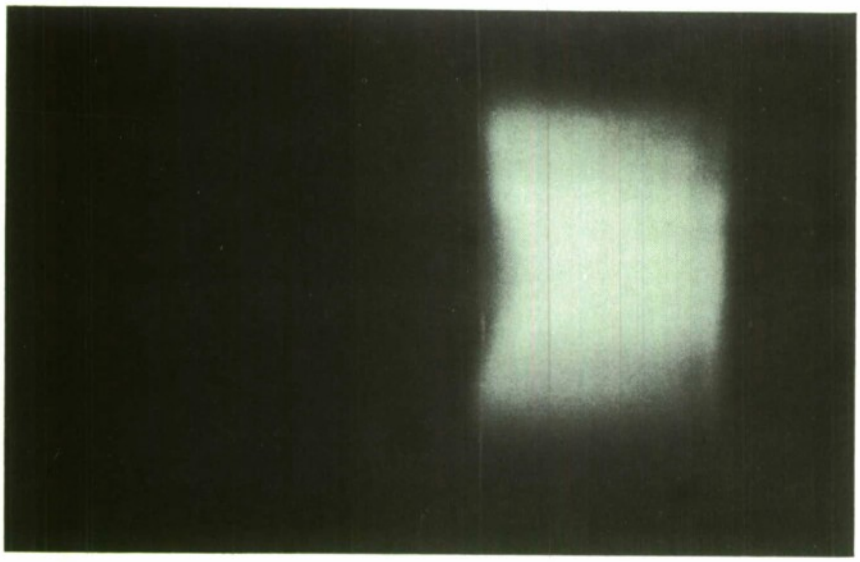


FIG. 21 X-RAY PICTURES OF GGP SERIAL NO. 224 FIRED AT 27°F



FRAME 5

T = 30 SEC

P = 697 PSIG

FRAME 6

T = 50 SEC

P = 648 PSIG

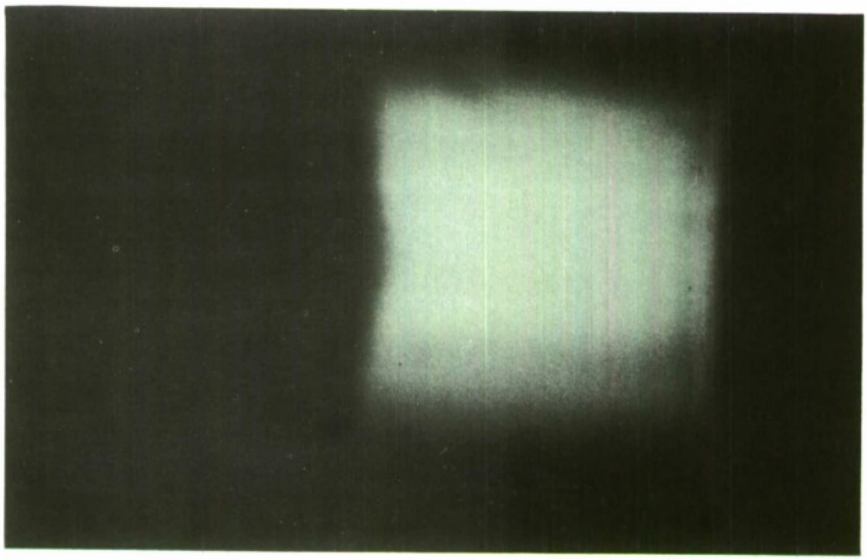
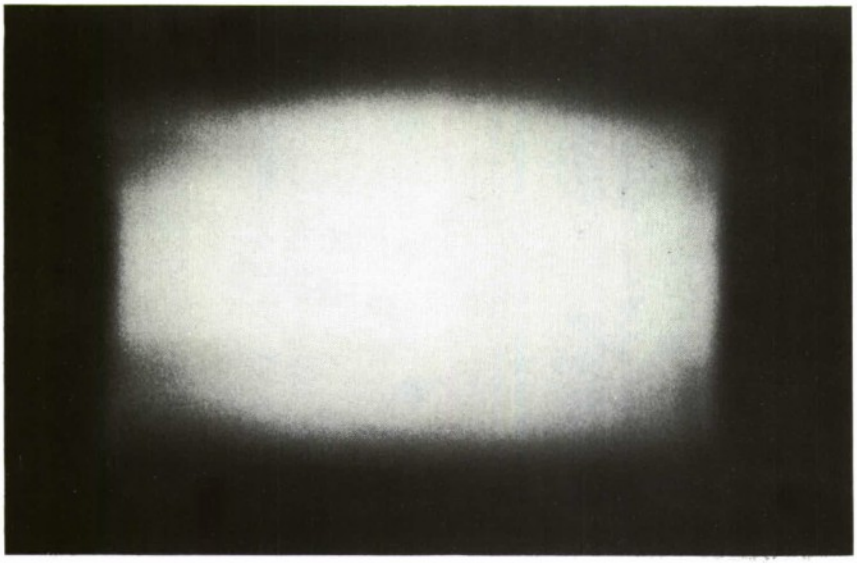


FIG. 22 X-RAY PICTURES OF GGP SERIAL NO. 224
FIRED AT 27°F



FRAME 7

T = 100 SEC

P = 621 PSIG

NOTE: THE GGP WAS SHIFTED FORWARD PRIOR TO FRAME 8

FRAME 8

T = 170 SEC

P = 643 PSIG

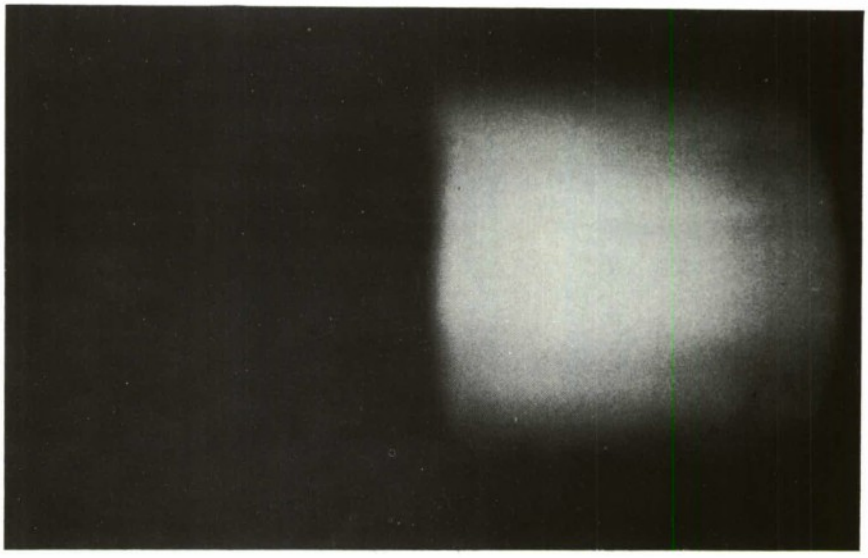
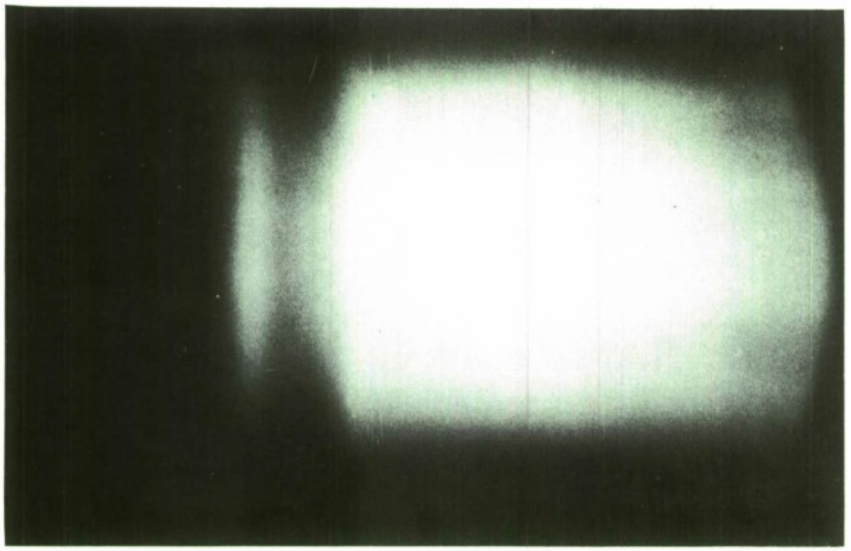


FIG. 23 X-RAY PICTURES OF GGP SERIAL NO. 224 FIRED AT 27°F



FRAME 9

T = 210 SEC

P= 659 PSIG

FRAME 10

T = 230 SEC

P = 714 PSIG

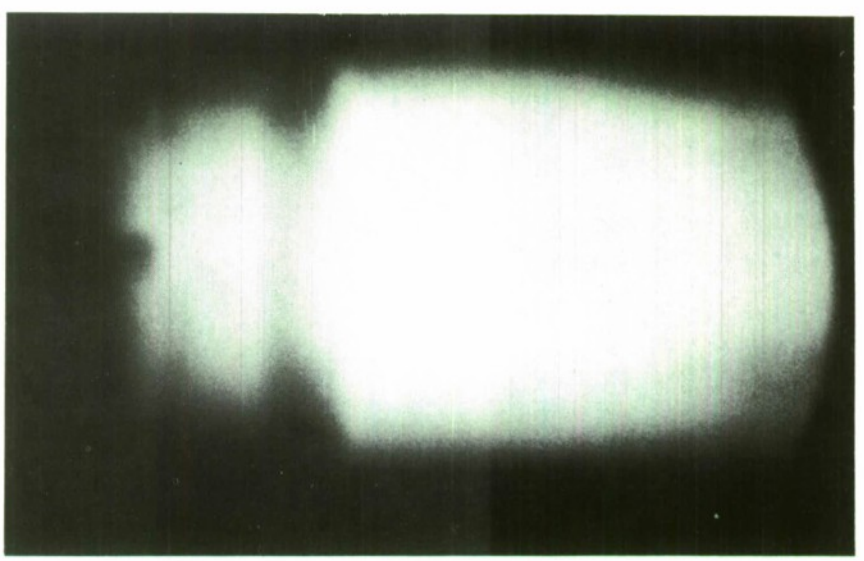


FIG. 24 X-RAY PICTURES OF GGP SERIAL NO. 224
FIRED AT 27°F

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			BIBLIOGRAPHIC (SUPPL., VOL., ETC.)		

SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
Subroc	SUBR	Chamber	CHAM		
Generator	GENR	Pressure	PRES		
Grain	GRAI	Time	TIME		
Radiography	RADG	Tape	TAPE		
Missile	MISL	Recorder	RECR		
Gas	GASE	Solid	SOLI		
WOX	WOXA	Instrumentation	INSM		
5A	ØØØ5	Contour	CNTU		
Propellant	FUEL	Variations	VART		
Burning	BURN				
X-ray	XRAY				
Movie	MOVE				

PRNC-NOL-5070/28 (5-62)

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 62-194)
RADIOGRAPHIC STUDY OF THE BURNING PROPELLANT GRAIN IN THE SUBROC GAS GENERATOR PACKAGE WOX-5A (U), by R. H. Stange. 1 Nov. 1962. 5p. illus., charts. Task RUSD 2 A000/212 1/W030 AO 001. CONFIDENTIAL

Burning propellant grain studies were conducted on SUBROC gas generator package (GGP) WOX-5A by use of radiographic techniques. Through use of image intensifier and lens system, continuous x-ray motion picture records were obtained of burning propellant grains. During tests, GGP chamber pressure versus time was recorded on FM instrumentation type tape recorder. Results confirmed theoretical predictions of propellant grain face contour changes during burning.

Abstract card is unclassified.

1. Missiles - Subroc
2. Generators, Gas
3. Generators - WOX-5A
4. Generators - Environmental tests

I. Title
II. Stange, Richard H.
III. Project

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